NuMI Beamline

Accelerator Advisory Committee Presentation

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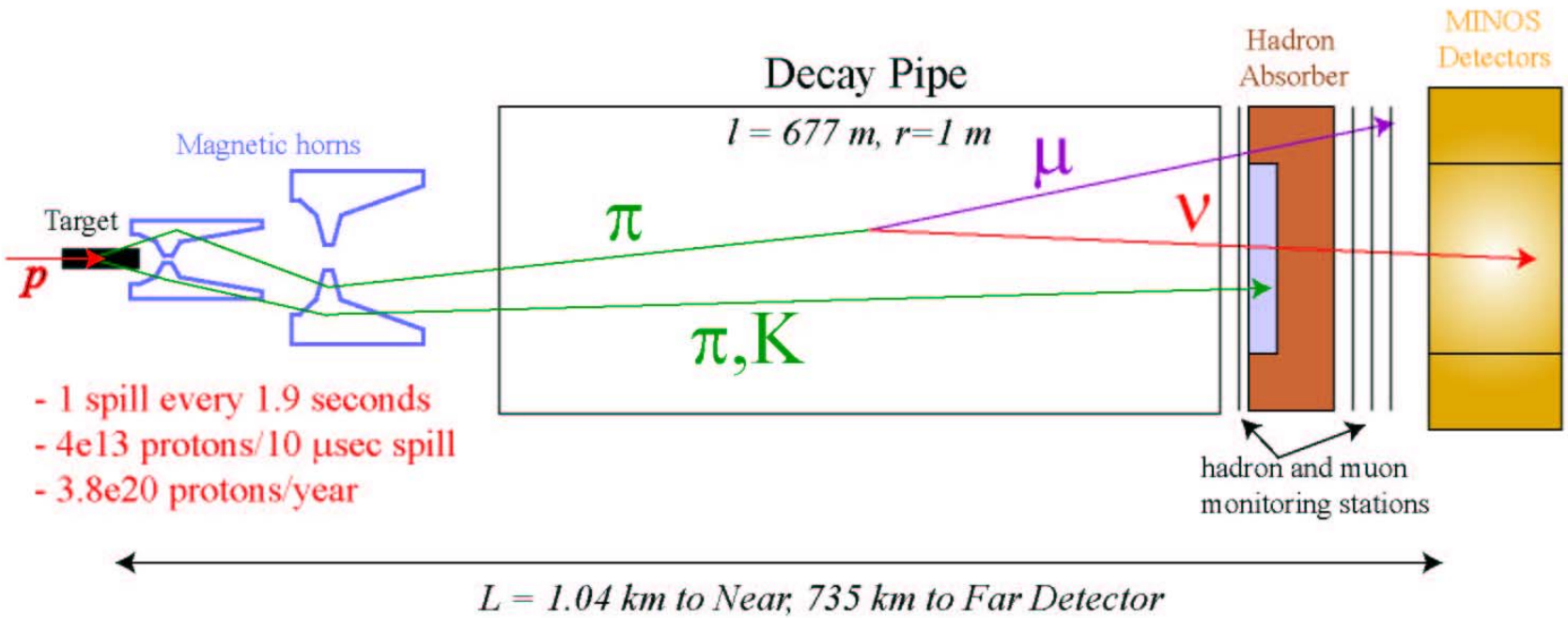
Producing a ν beam at NuMI

120 GeV/c protons strike graphite target

Magnetic horns focus charged mesons (pions and kaons)

Pions and kaons decay giving neutrinos



Upgrading NuMI for Higher Power

- NuMI Beamline designed for 400 kW proton beam.
- Prepare for 700 kW to 1 MW by year ~2010.
- Increase intensity and reduce cycle time

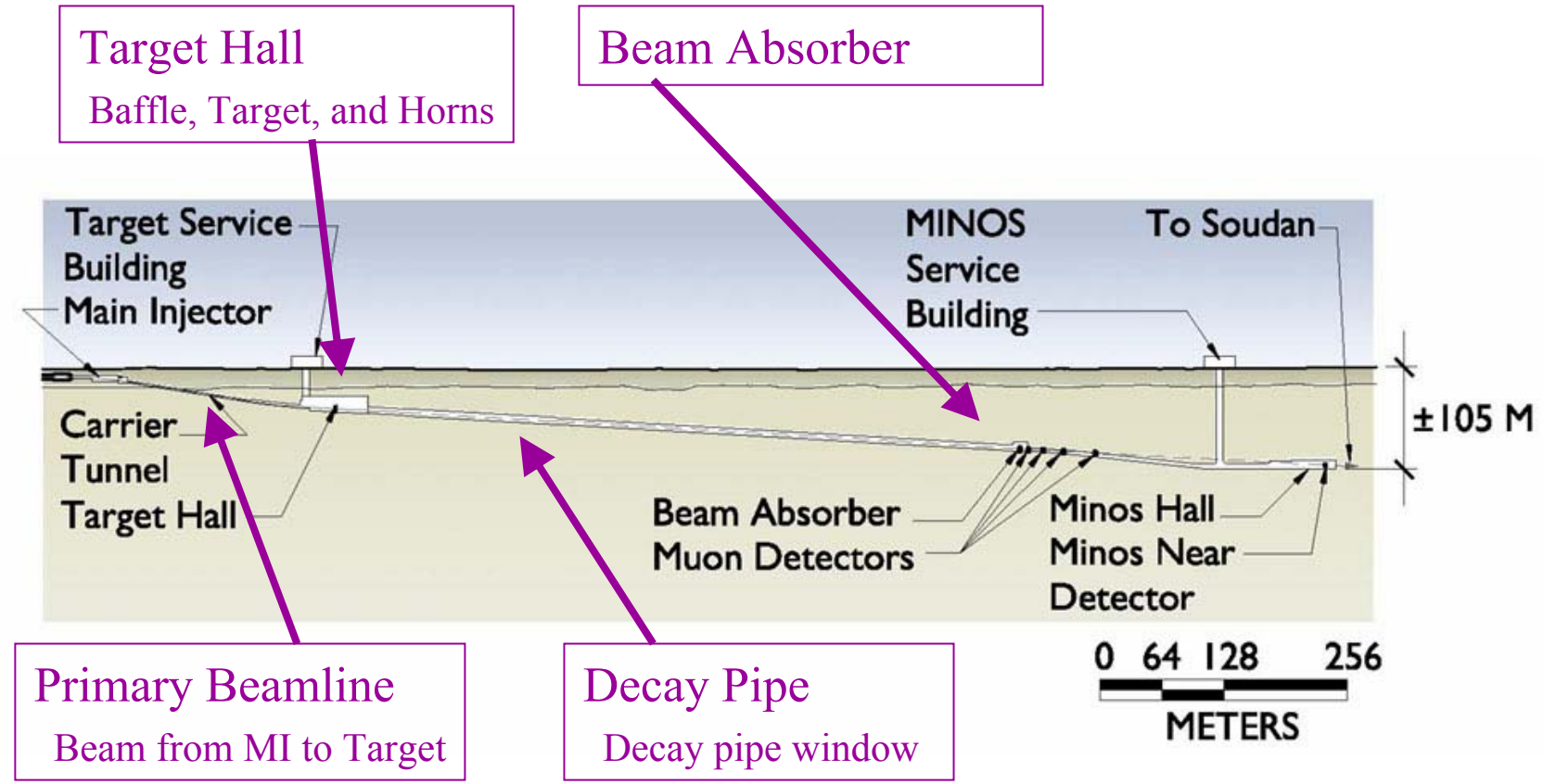
	NuMI Design	Slip-stacking in RR 1	Slip-stacking in RR 2	Momentum Stacking in Accumulator 1	Momentum Stacking in Accumulator 2
Cycle time (seconds)	1.9	1.5	1.3	1.6	1.3
MI intensity (10^{13} ppp)	4.0	5.4	5.4	9.6	7.2
Beam power (kW)	400	700	780	1150	1040
Protons (10^{17} prot/hr)	0.77	1.33	1.46	2.16	1.94

Issues Related to More Power

- Removing larger heat load
  - 1 MW beam in $\Rightarrow$ 1 MW of heat out
- Thermal shock
  - Increased per pulse intensity
- Mis-alignment from thermal expansion
  - Alignment important for experiment systematic error
- DC thermal stress limit and heat damage to material
- Radiation damage lifetime of materials
- Safety
  - Radiation safety
  - Groundwater Protection
  - Airborne Activation
  - Prompt Radiation
  - Residual Activation

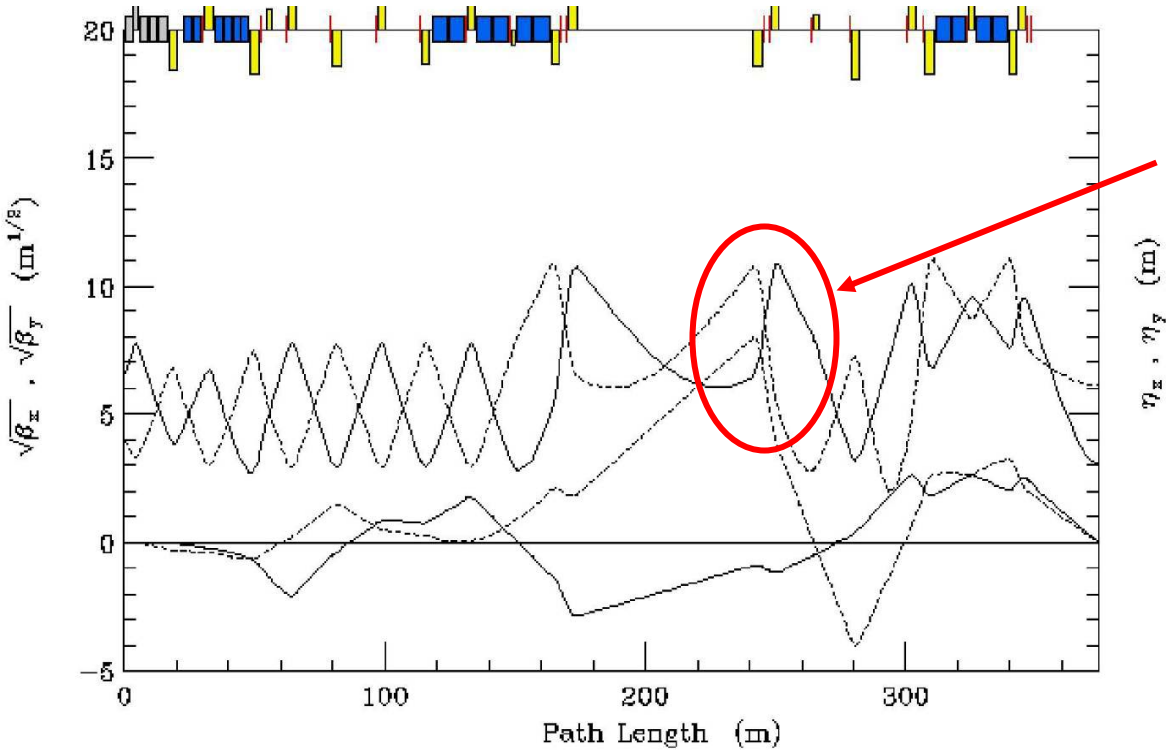
Engineering support freed up after shutdown to look into these issues for the major NuMI components

Major Components of NuMI Beamline



Primary Beamline Optics

Plenty of aperture.



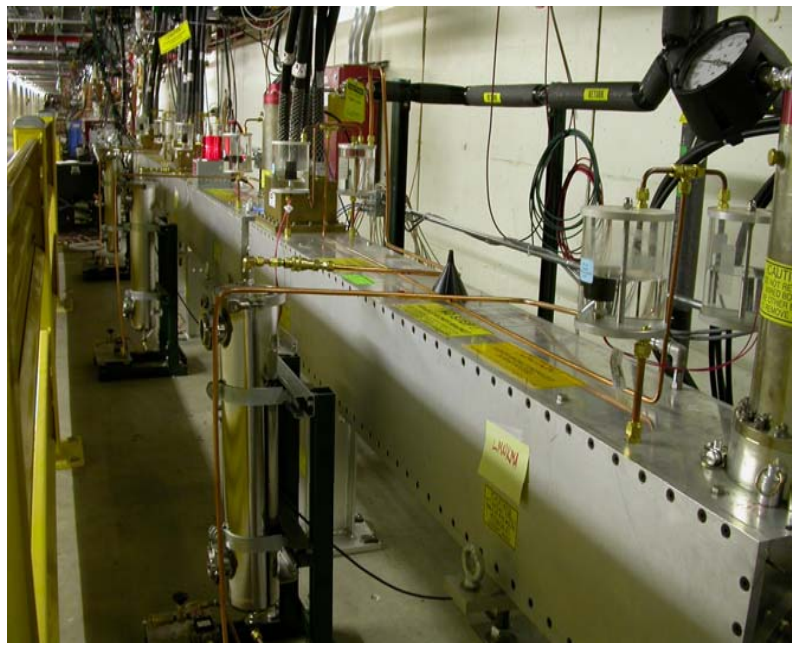
@ max dispersion point

Beam size is ±7 mm (95%)
Aperture is ±35 mm

Keep fractional beam losses below 10^{-5}
(Groundwater protection, residual activation)

NuMI Extraction Kickers

- Kicker and Lambertsons are fine
  - Aperture is sufficient
  - Extraction is clean
  - No issues with radiation
- Available charging time drops
  - From 1.3 secs ⇒ 0.7 secs
  - Upgrade charging supply
  - Upgrade fluorinert to water heat exchanger



NuMI extraction kickers in MI Tunnel

Primary Beam Concern

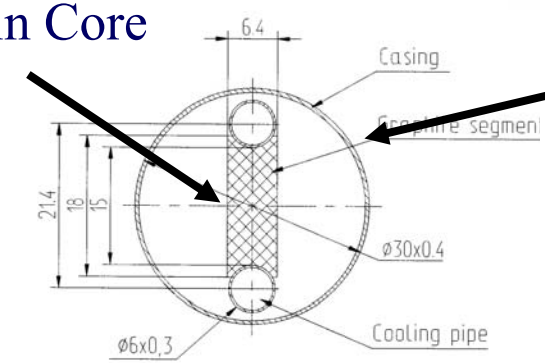
- Reduced Cycle Time
  - 1.3 second rep-rate
    - Build a few new magnets, and re-work some magnets/PS
  - Faster than 1.3 sec rep-rate
    - Crosses a threshold – requires significantly more resources
    - Presently not being considered.

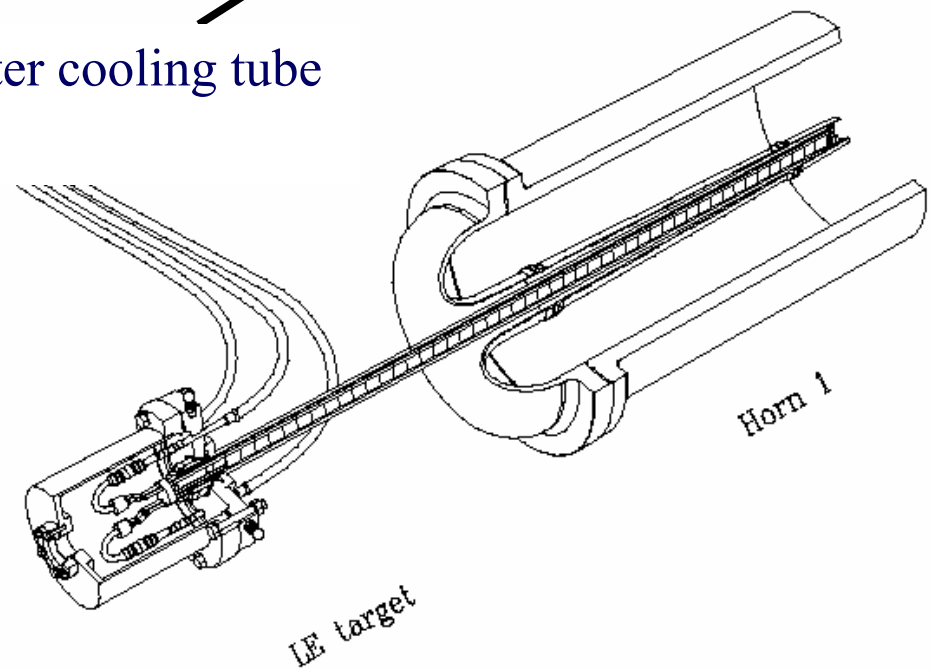
- Increased Intensity
  - Crossing a threshold: **Single bad pulse can cause component damage.**
  - Presently the Beam Permit System precludes a 2nd bad pulse.
  - In the future monitor power supply currents to ~ 0.01% for Beam Permit System

Low Energy Target

Graphite Fin Core

Water cooling tube





Low Energy Target fits inside the horn

Medium Energy Neutrino Beam

Medium Energy Beam is better for NOvA (14 mrad off-axis)

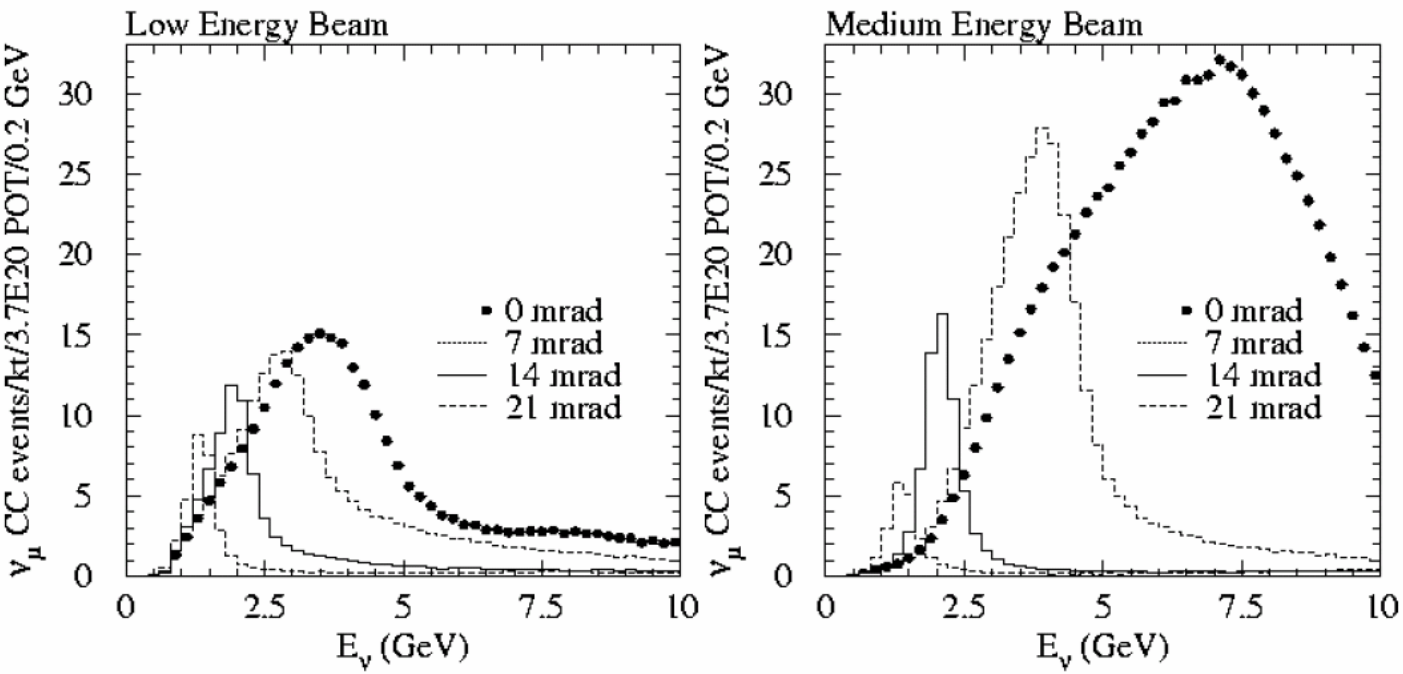
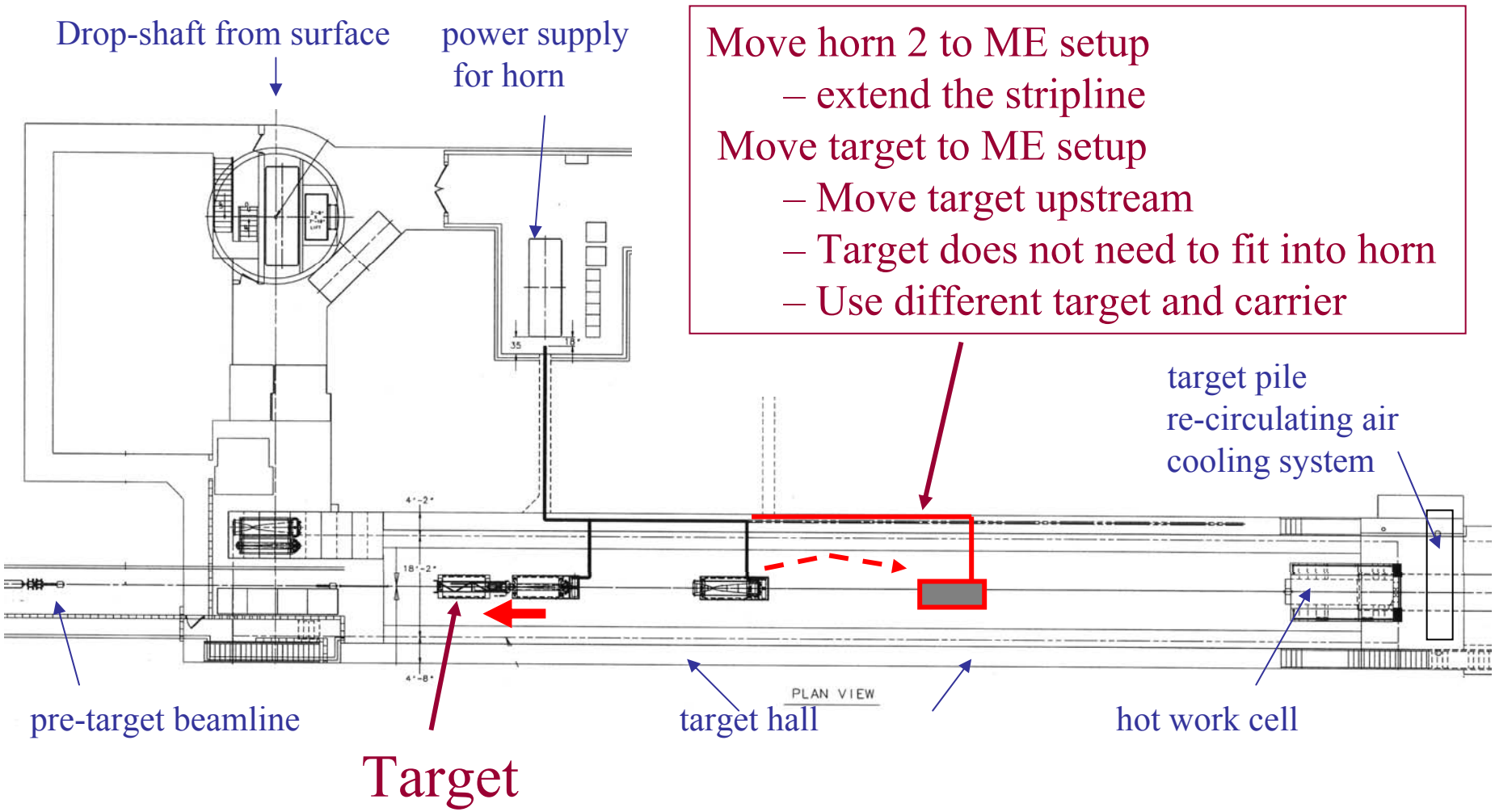


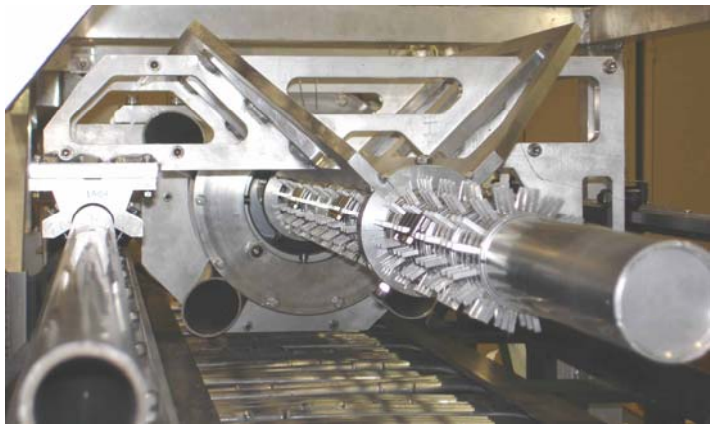
Fig. 2.7: CC ν_μ event rates expected under a no-oscillation hypothesis at a distance of 800 km from Fermilab and at various transverse locations for the NuMI low-energy beam configuration (left) and medium-energy beam configuration (right).

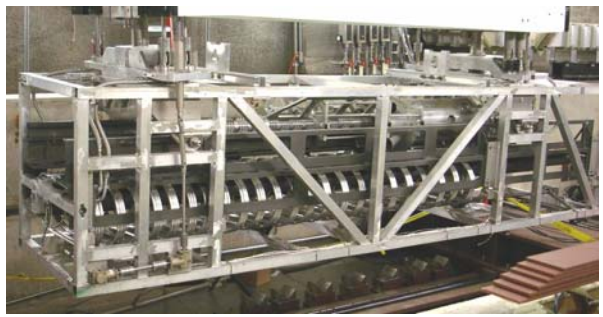
NuMI Target Hall Layout for NOvA

Medium Energy Beam



Target, Baffle, Target Carrier installed in target pile

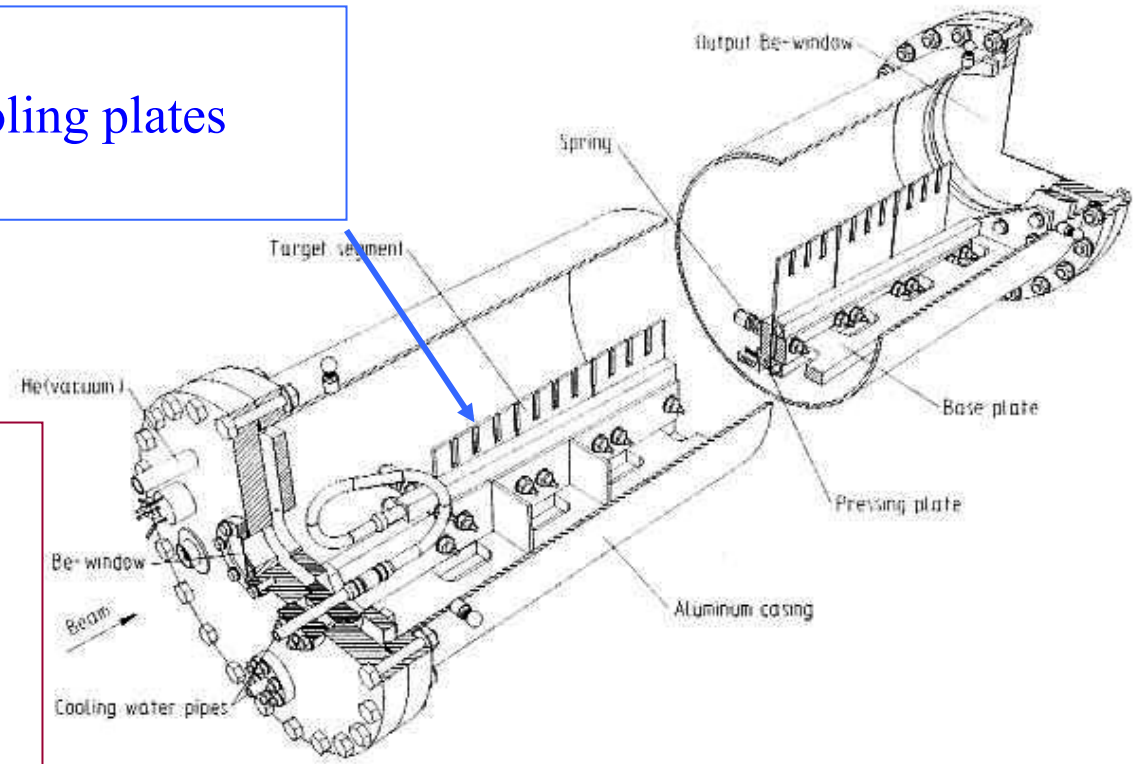




Medium Energy Target Concepts

ME Target design does not need to fit inside horn

Fin design:
- Graphite fins clamped with cooling plates
- Provides more water cooling

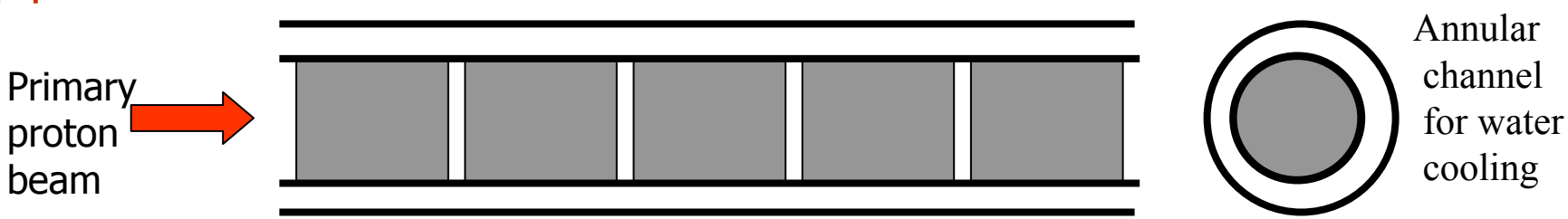


Other options:
- Specify larger beam spot size
- Thicker graphite fin
- Higher Power target design

These may cost some neutrinos

Target Design for yet higher power

Encapsulation of graphite cylinders (segments) with a prestress of about 10 MPa into stainless steel or aluminum thin-walled pipe:



- Provides an integrity of the target core and keeps it even in the case of thermo-mechanical or radiation damages of some segments
- Prevents a direct contact of the cooling water with the heated surface of graphite
- Provides a good thermal contact between graphite and metal pipe

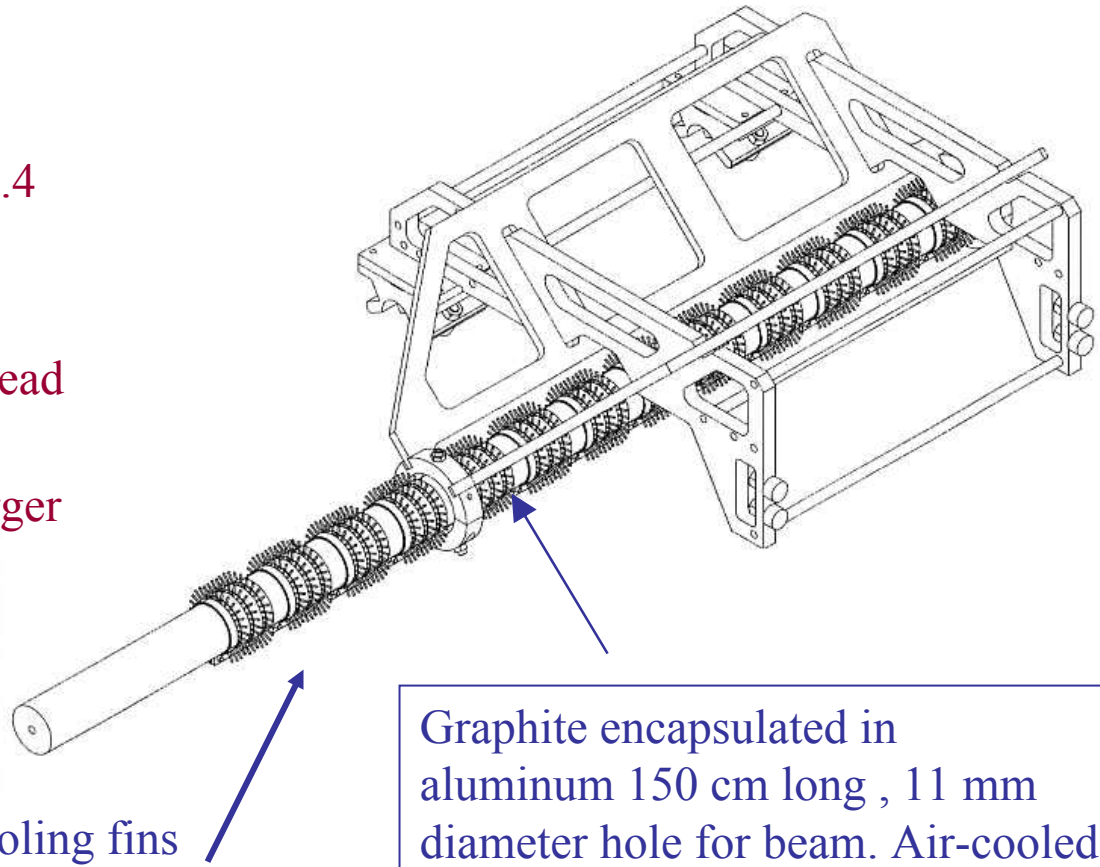
Suitable for higher beam power (maybe even 2 MW)

but ~10% fewer neutrinos / POT

Baffle Modifications

Baffle protects beamline elements from single pulse mis-steered beam.

- OK for thermal shock up to 5.4 E13?
- 75% more fins for cooling.
- Move further upstream to spread out shower more.
- Increase hole diameter for larger beam size



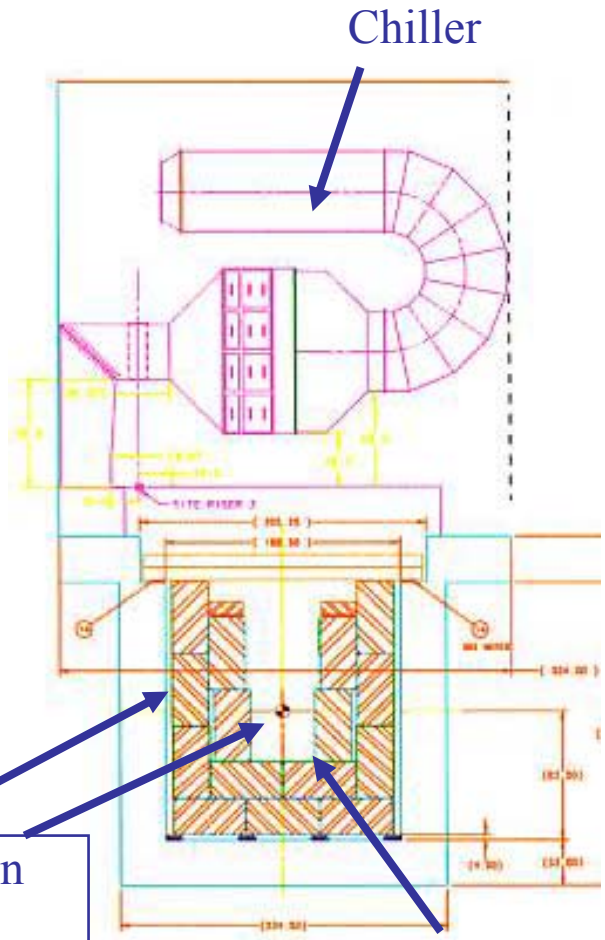
Space to increase air-cooling fins

Graphite encapsulated in aluminum 150 cm long , 11 mm diameter hole for beam. Air-cooled

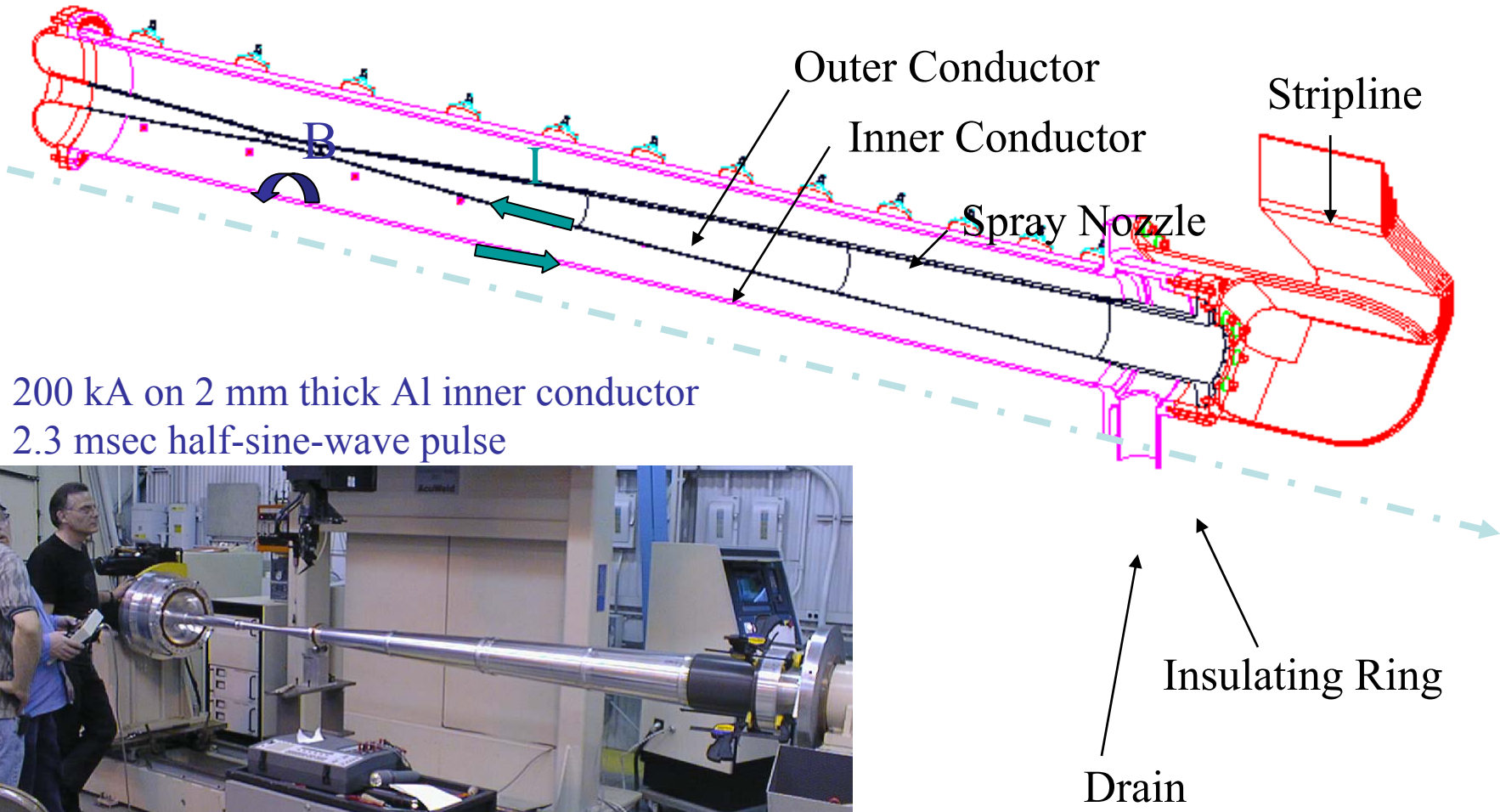
Target Hall Air Conditioning

- Target Hall Cooling
  - Closed loop air recirculating system
  - Designed to maintain positional stability of target/horns
  - 25,000 cfm air flow
  - 240 kW of cooling
  - 18 mph wind in beam channel

- Need to upgrade for 700 kW
- For 1 MW may need water cooling



NuMI Magnetic Horns



200 kA on 2 mm thick Al inner conductor
2.3 msec half-sine-wave pulse

Horn Modifications

Inner conductor should be OK up to 1 MW
(Needs study to confirm)

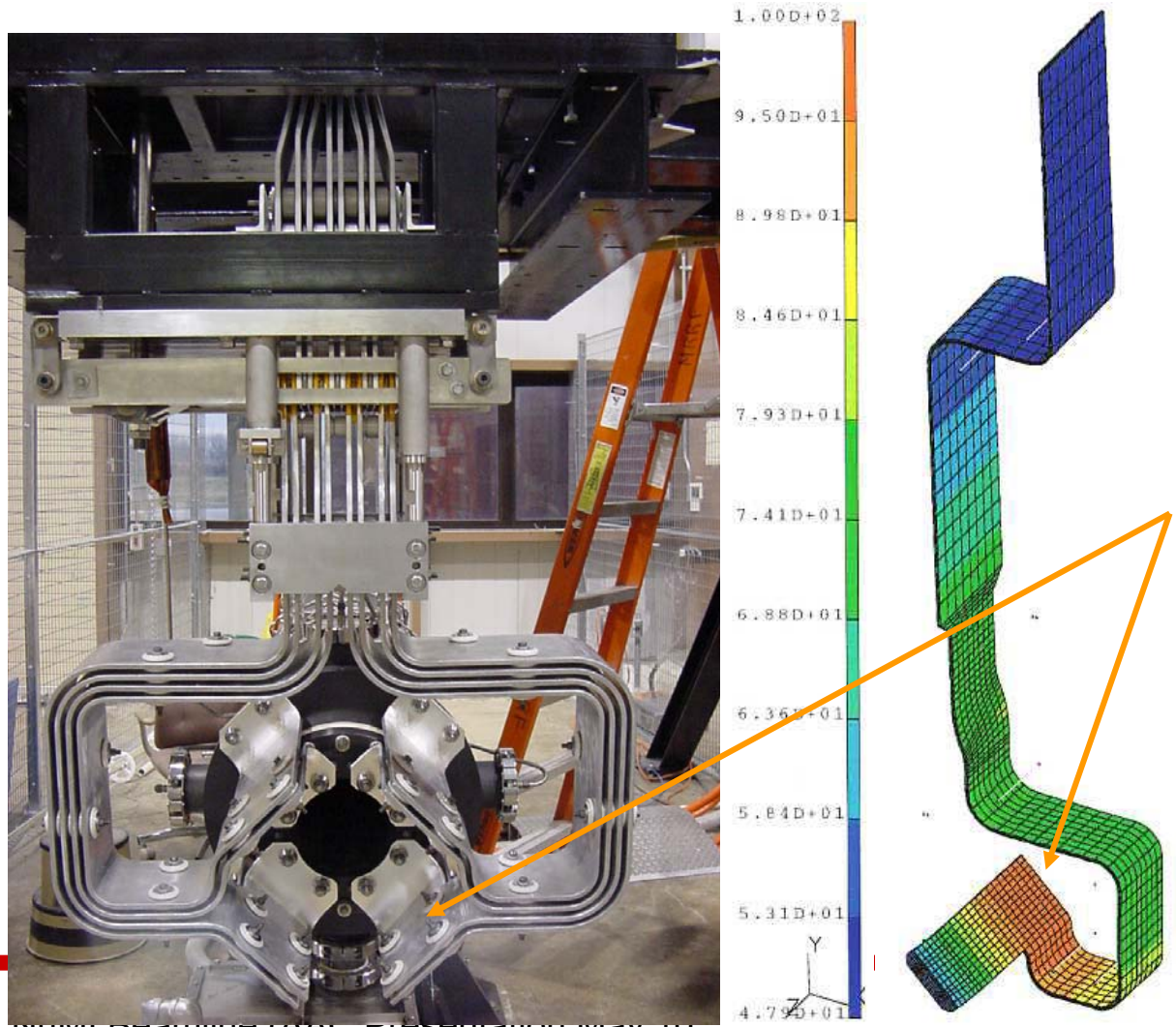
Beam heating in horn 1 outer conductor is an issue (is 12 kW M.E. beam base design)

Uneven water cooling can cause
outer conductor to "potato-chip",
causing misalignment of focusing

Reduce thickness of outer conductor
(it is now 1 inch)
or add more cooling to maintain uniformity to ~ 6 deg C

Also must take closer look at all parts which are not currently water cooled

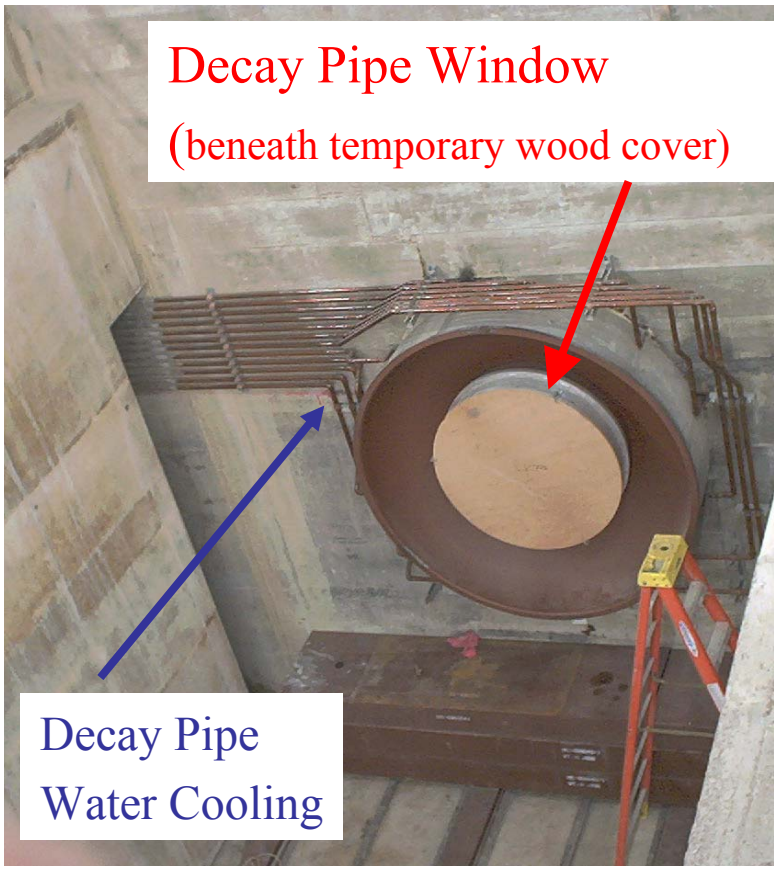
Horn Power Strip-line Heating



Aluminum stripline reaches 100 deg C with air at 13 deg C in base design

Will need to be checked

Decay Pipe and Hadron Aborber



- Decay pipe
  - is under vaccum
  - cooling can be increased with faster water flow.
- Decay Pipe Window
  - Thin aluminum window
  - Need to protect against single pulse accidents at the higher intensity
- Hadron Aborber
  - Needs investigating

Conclusions

- NuMI Beamline requires significant upgrades to achieve 700 kW or 1MW
- The major issues are identified and we have conceptual ideas
- Engineering support is starting to look into the upgrade issues in more detail
- Near term goal is a conceptual design report by Autumn 2006 for 700 kW operations in 2010.
- Working towards 1 MW design.